MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2017/2018

ETN2016 – ANALOG COMMUNICATIONS

(All Section / Groups)

12 MARCH 2018
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 11 pages (including the cover page) with 4 Questions only.

2. Attempt all of the **FOUR** questions. All questions carry equal marks and the distribution of the marks for each question is given.

3. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Consider a periodic signal $v(t)$ shown in Figure Q1.1.

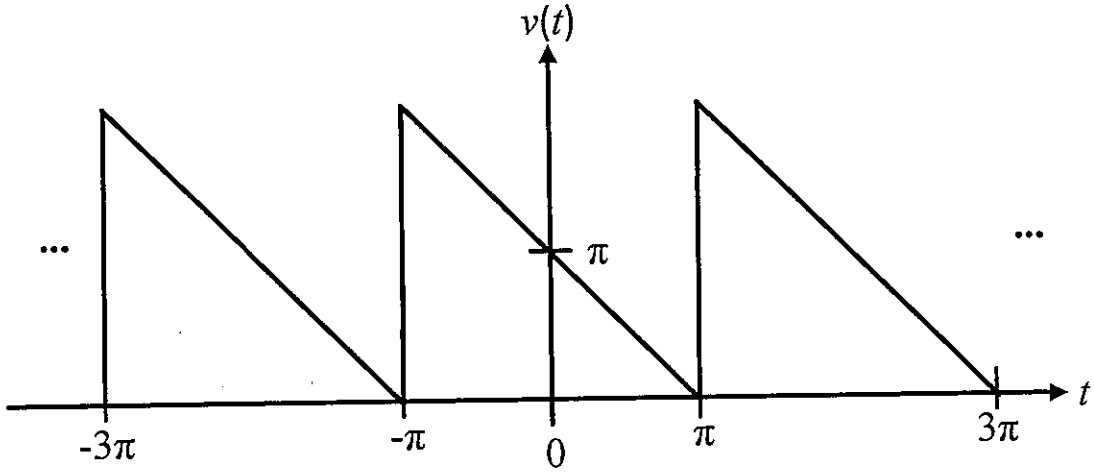

Figure Q1.1: Periodic signal $v(t)$.

(i) Compute the mean value of the $v(t)$.

[2 marks]

(ii) Determine the trigonometric Fourier series of $v(t)$.

[11 marks]

(iii) Sketch the single sided magnitude spectrum of $v(t)$ up to the 4th harmonic, i.e., $n = 0, 1, 2, 3, 4$, where $f = nf_0$ is the nth harmonic frequency, $f_0 = \frac{1}{T_0}$, and T_0 denotes the period of $v(t)$.

[3 marks]

(b) The Fourier transform of the triangular pulse $m(t)$ shown in Figure Q1.2 is given as $M(f) = \frac{1}{4\pi^2 f^2}\left(e^{j2\pi f} - j2\pi f e^{j2\pi f} - 1\right)$. By applying the properties of the Fourier transform, determine the Fourier transform of the following signals:

(i) $r(t)$ shown in Figure Q1.3.

[2 marks]

(ii) $y(t)$ shown in Figure Q1.4.

[7 marks]

Continued .....

Question 1

(b)

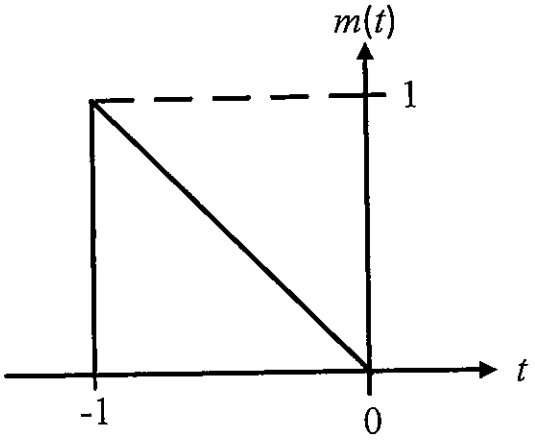

Figure Q1.2: Signal $m(t)$.

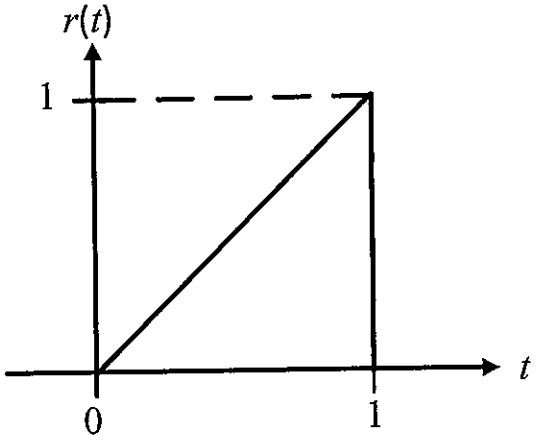

Figure Q1.3: Signal $r(t)$.

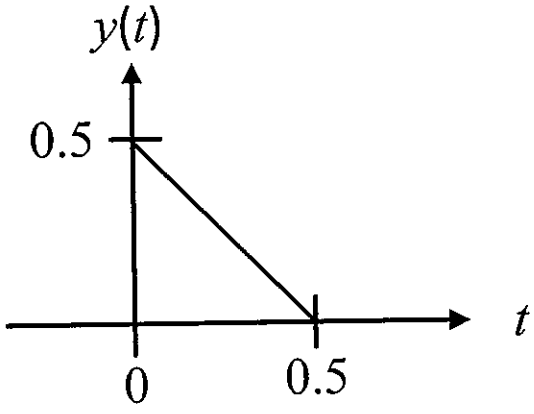

Figure Q1.4: Signal $y(t)$.

Continued .....

Question 2

(a) Consider the double sided magnitude spectrum of the message signal $W(f)$ illustrated in Figure Q2.1.

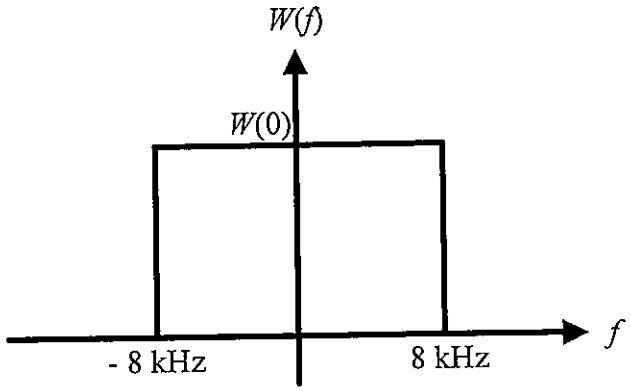

Figure Q2.1: Double sided magnitude spectrum $W(f)$.

Calculate the total number of radio stations that can be simultaneously accommodated in a bandwidth of 40 kHz for the following modulation schemes:

(i) Double sideband large carrier (DSB-LC). [2 marks]

(ii) Double sideband suppressed carrier (DSB-SC). [2 marks]

(iii) Single sideband (SSB). [2 marks]

(b) The transmitter of a radio station operating using DSB-LC modulation scheme has a carrier power of 12 kW and the modulation index is 0.75. Compute the following:

(i) The power efficiency of the DSB-LC scheme. [2 marks]

(ii) The total power radiated by the antenna of the transmitter. [2 marks]

(iii) The power contained in the lower sideband of the modulated signal. [2 marks]

Continued .....

Question 2

(c) A message signal $m(t)$ modulates a carrier signal $c(t) = A_c \cos(2\pi f_c t)$ using DSB-SC modulation scheme.

(i) Derive the time-domain and frequency-domain expressions for the DSB-SC modulated signal $s(t)$.

[4 marks]

(ii) Assume that $m(t)$ has a spectrum as shown in Figure Q2.2. Sketch the magnitude spectrum of the DSB-SC modulated signal.

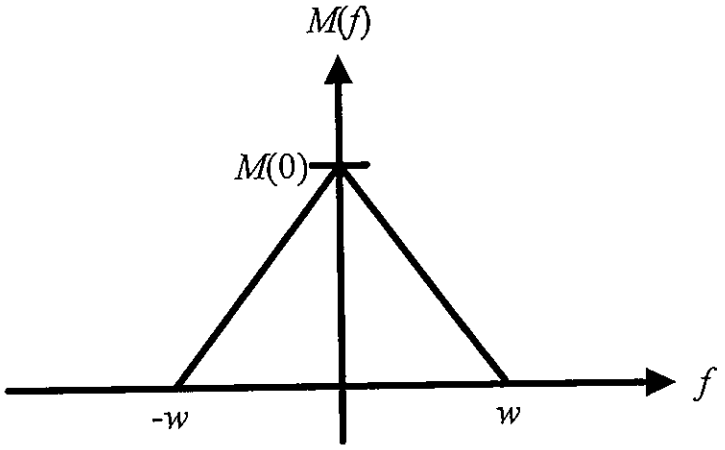

Figure Q2.2: Spectrum of message signal $m(t)$.

[3 marks]

(iii) State one advantage of DSB-SC modulation scheme in comparison to SSB modulation scheme.

[1 mark]

(d) Sketch the block diagram of SSB modulator and explain its working principle.

[5 marks]

Continued .....

Question 3

(a) Consider a sinusoidal modulating signal $m(t)=A_m\cos(2\pi f_m t)$ that phase-modulates a carrier wave of frequency f_c and the resulting phase modulated signal is $x(t)$. Assume that the phase sensitivity is k_p. Determine the expressions for the following:

(i) Phase deviation of $x(t)$.

[1 mark]

(ii) Phase modulated signal $x(t)$.

[1 mark]

(iii) Instantaneous phase of $x(t)$.

[1 mark]

(iv) Instantaneous frequency of $x(t)$.

[2 marks]

(b) Consider a frequency modulated signal that is expressed as follows:

$$s(t)=3.5\cos\left\{(2\pi)(1.5\times10^6 t)+3\sin\left[(2\pi)(2\times10^4 t)\right]\right\}$$

Assume that $s(t)$ is supplied to a load of 1 ohm.

(i) Is $s(t)$ narrowband frequency modulated or wideband frequency modulated? Justify your answer.

[2 marks]

(ii) Determine the frequency of the carrier signal.

[1 mark]

(iii) Calculate the frequency deviation.

[2 marks]

(iv) Calculate the bandwidth of $s(t)$ based on the Carson's rule.

[2 marks]

(v) Calculate the bandwidth of $s(t)$ by using the table of Bessel function of the first kind.

[2 marks]

(vi) Compute the amount of transmission power contained in the carrier frequency.

[2 marks]

(vii) Compute the amount of transmission power contained in the sidebands.

[2 marks]

Continued .....

Question 3

(c) Consider an audio signal $v(t)$ that frequency modulates a carrier wave of frequency $f_c = 1$ MHz. The frequency of $v(t)$ ranges from 20 Hz to 15 kHz and the amplitude of $v(t)$ stays at ± 3 V. Calculate the maximum frequency deviation of the frequency modulated signal and the frequency sensitivity if the modulation index $\beta = 3$.

[4 marks]

(d) Explain the capture effect that is associated with FM reception.

[3 marks]

Question 4

(a) Explain two characteristics of white noise.

[3 marks]

(b) Figure Q4.1 shows the block diagram of an amplitude modulation (AM) receiver. $x(t) = s(t) + n(t)$ is the input to the envelope detector, where $s(t) = A_c[1 + k_a m(t)]\cos(2\pi f_c t)$ is the amplitude modulated signal, $n(t)$ represents the white noise with power spectral density of $\frac{N_0}{2}$, $A_c \cos(\omega_c t)$ is the carrier signal, $m(t)$ is the message signal with bandwidth of W, and k_a is the amplitude sensitivity of the modulator. Assume that the band-pass filter has unity gain and an equivalent noise bandwidth of B_T, $E[m(t)] = 0$, and $P = E[m^2(t)]$, where $E[\ ]$ is the expectation operator.

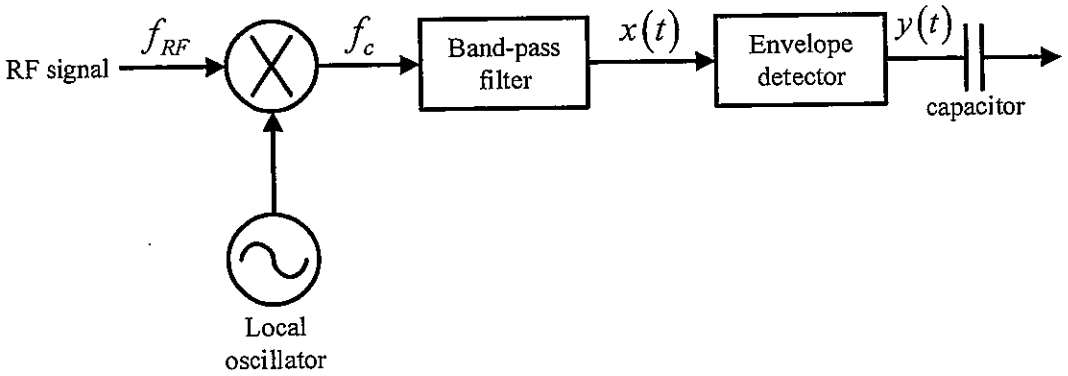

Figure Q4.1: Block diagram of an AM receiver.

Continued .....

Question 4

(b) Determine the following:

(i) Average power of the signal component at the output of the capacitor.

[6 marks]

(ii) Post-detection signal-to-noise ratio (SNR) of the AM receiver (SNR at the output of the capacitor).

[4 marks]

(c) Design a double conversion superheterodyne frequency modulation (FM) radio receiver that consists of two consecutive intermediate frequency (IF) stages and utilizes high-side injection (high tracking) at both stages. The receiver can be tuned to receive radio frequency (RF) signal from 80 MHz to 115 MHz. The intermediate frequencies for the first stage and second stage are 10.7 MHz and 455 kHz, respectively. Calculate the following:

(i) The image frequency at the respective stage (first stage and second stage).

[6 marks]

(ii) The local oscillator frequency required at the respective stage (first stage and second stage).

[6 marks]

Continued .....

APPENDIX

Fourier Transform Pairs

$x(t)$	$X(f)$
$\delta(t)$	1
$\delta(t-t_o)$	$e^{-j2\pi ft_o}$
1	$\delta(f)$
$e^{j2\pi f_o t}$	$\delta(f-f_o)$
$u(t)$	$\frac{1}{2}\delta(f)+\frac{1}{j2\pi f}$
$e^{-at}u(t)$	$\frac{1}{a+j2\pi f}$, for $a>0$
$e^{at}u(-t)$	$\frac{1}{a-j2\pi f}$, for $a>0$
$e^{-a\lvert t\rvert}$	$\frac{2a}{a^2+(2\pi f)^2}$, for $a>0$
$rect\left(\frac{t}{T}\right)$	$T\text{sinc}(fT)$
$\text{sinc}(2Wt)$	$\frac{1}{2W}rect\left(\frac{f}{2W}\right)$
$\Delta\left(\frac{t}{T}\right)$	$\frac{T}{2}\text{sinc}^2\left(\frac{fT}{2}\right)$
$W\text{sinc}^2(Wt)$	$\Delta\left(\frac{f}{2W}\right)$
$e^{-\pi t^2}$	$e^{-\pi f^2}$
$\cos(2\pi f_o t)$	$\frac{1}{2}\delta(f-f_o)+\frac{1}{2}\delta(f+f_o)$
$\sin(2\pi f_o t)$	$\frac{1}{2j}[\delta(f-f_o)-\delta(f+f_o)]$

Continued .....

Fourier Transform Properties

Let $x(t) \Leftrightarrow X(f)$, $x_1(t) \Leftrightarrow X_1(f)$ and $x_2(t) \Leftrightarrow X_2(f)$; and a, b, t_o and f_o scalar quantities.	
Linearity	$ax_1(t)+bx_2(t) \Leftrightarrow aX_1(f)+bX_2(f)$
Scaling ($a \neq 0$)	$x(at) \Leftrightarrow \frac{1}{\lvert a \rvert} X\left(\frac{f}{a}\right)$
Time Shifting	$x(t-t_o) \Leftrightarrow X(f)e^{-j2\pi f t_o}$
Frequency Shifting	$x(t)e^{j2\pi f_o t} \Leftrightarrow X(f-f_o)$
Time Convolution	$x_1(t) * x_2(t) \Leftrightarrow X_1(f)X_2(f)$
Frequency Convolution	$x_1(t)x_2(t) \Leftrightarrow X_1(f) * X_2(f)$
Time Differentiation	$\frac{d^n}{dt^n}x(t) \Leftrightarrow (j2\pi f)^n X(f)$
Frequency Differentiation	$(-jt)^n x(t) \Leftrightarrow \frac{d^n}{df^n}X(f)$
Time Integration	$\int_{-\infty}^{t} x(\tilde{t})d\tilde{t} \Leftrightarrow \frac{X(f)}{j2\pi f}+\frac{1}{2}X(0)\delta(f)$
Frequency Integration	$x(t)u(t) \Leftrightarrow \int_{-\infty}^{f} X(\tilde{f})d\tilde{f}$

Useful Trigonometric Identities

$$\sin A \sin B = \frac{1}{2}\left[\cos(A-B)-\cos(A+B)\right]$$

$$\cos A \cos B = \frac{1}{2}\left[\cos(A+B)+\cos(A-B)\right]$$

$$\sin(A+B) = \sin A \cos B + \cos A \sin B$$

$$\cos(A+B) = \cos A \cos B - \sin A \sin B$$

$$\sin\theta = \frac{1}{2j}\left[e^{j\theta}-e^{-j\theta}\right]$$

$$\cos\theta = \frac{1}{2}\left[e^{j\theta}+e^{-j\theta}\right]$$

Continued .....

Table of Bessel functions of the first kind

	$J_n(\beta)$							
n	$\beta = 0.2$	$\beta = 0.3$	$\beta = 0.5$	$\beta = 0.7$	$\beta = 1.0$	$\beta = 2.0$	$\beta = 3.0$	$\beta = 5.0$
0	0.990	0.978	0.938	0.881	0.765	0.224	-0.260	-0.178
1	0.100	0.148	0.242	0.329	0.440	0.577	0.339	-0.328
2	0.005	0.011	0.031	0.059	0.115	0.353	0.486	0.047
3		0.001	0.003	0.007	0.020	0.129	0.309	0.365
4				0.001	0.002	0.034	0.132	0.391
5						0.007	0.043	0.261
6						0.001	0.011	0.131
7							0.003	0.053
8								0.018
9								0.006
10								0.001

End of Paper